Adaptive Sensor Fleet (ASF)

Code 588 / Jeff Hosler

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Supervisory control system that is designed to use a collection of heterogeneous robotic platforms to optimally perform observations of dynamic environments driven by high-level goals.

Objectives / Benefits:

Enable instruments to rapidly respond to dynamic science events *through science goal driven autonomy*.

Automatically optimize target selection and instrument operation *based on near real-time science data analysis and predictive modeling.*

Demonstrate multi-platform autonomous collaboration, driven by scientific goals *to obtain measurements not currently possible.*

The concepts addressed in the design of the ASF lay the foundation for a *dynamic "Sensor Web"* using stationary, surface moving (water or land), airborne, and spacecraft instruments to generate a dynamic network of sensors to achieve the defined science goals.

ASF Test Domain

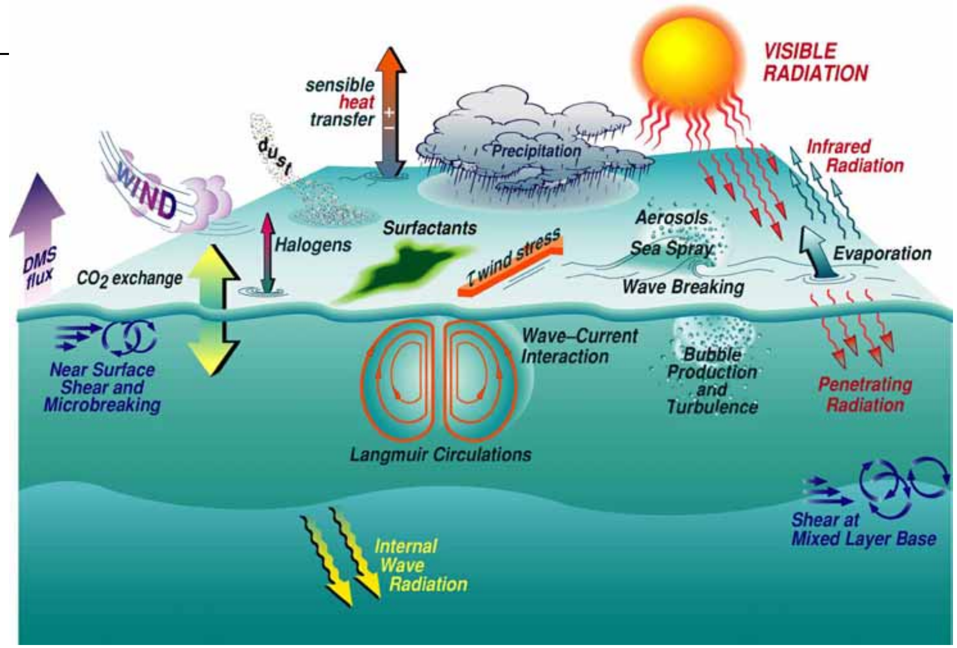
Ocean Atmosphere Sensor Integration System (OASIS)

- The OASIS objective is to provide low-cost ($20K each) mobile, self-navigating surface platforms for ocean sensors, as an alternative to buoys. Benefits of OASIS focus on the ability to navigate to make measurements, and then return home to recalibrate, and reuse instruments which may otherwise be discarded. This will generate significant cost savings for NASA especially in the area of data Calibration / Validation of remote sensing satellite measurements.

- OASIS provides a perfect low-cost domain to demonstrate the capabilities of ASF.
  - Remote commanding
  - Semi-autonomous
  - Science Collection
  - Heterogeneous

- Water test demonstration using 3-6 OASIS craft under ASF control planned for FY05.

- The OASIS proposed plan for FY05 is to apply $4M to applying the ASF technology to NOAA applications



Many different types of ocean / atmosphere measurements can be collected by OASIS platforms.

- Instruments planned
  - Thermistor (temperature and salinity)
  - Conductivity (salinity)
  - GPS (location, currents)
  - Fluorometer (chlorophyll)
  - Anemometer (wind)
  - Others

Scientific Value / Need

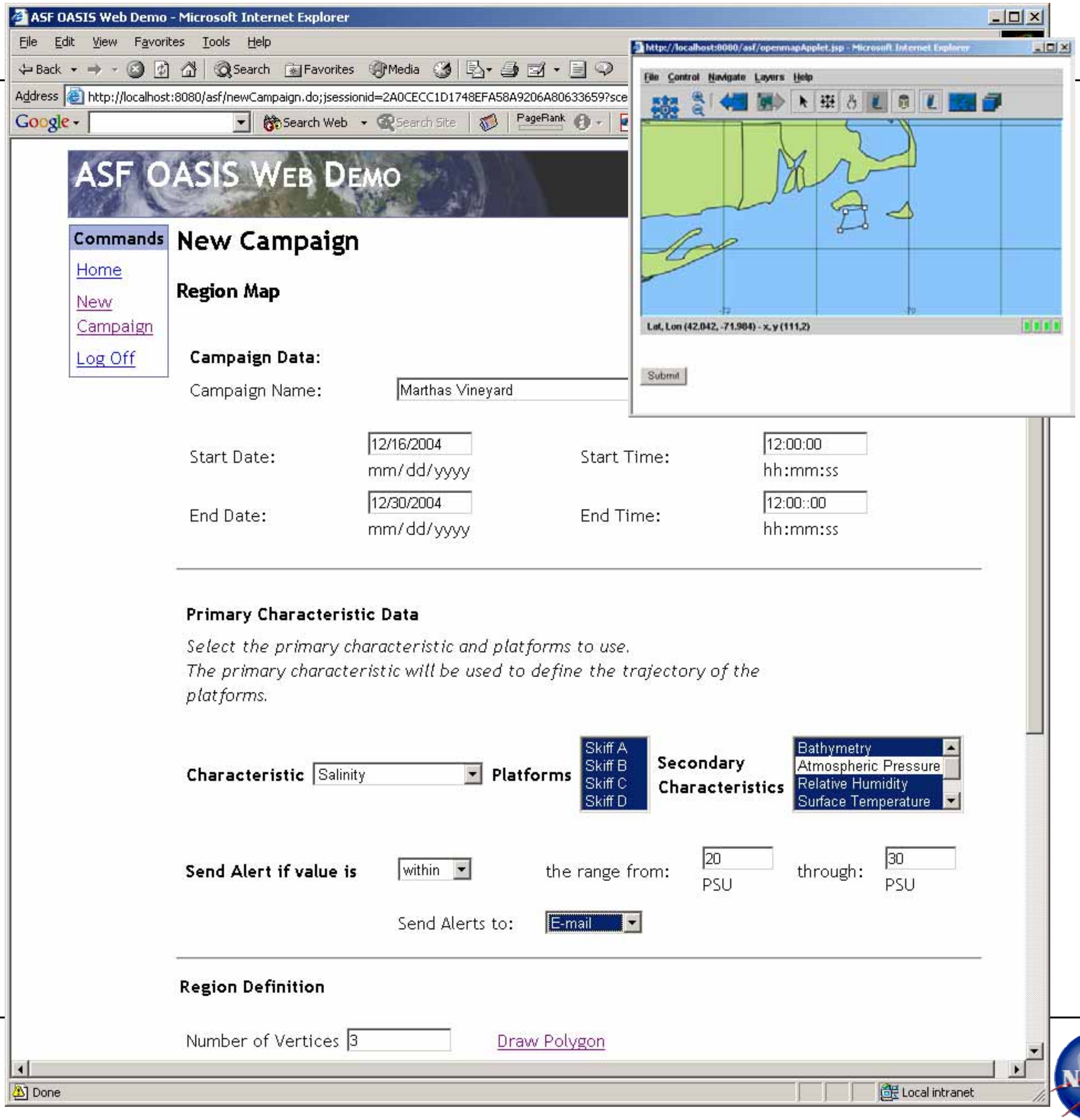
- *Why couldn't this be done via remote sensing or via static or drifting buoys?*
  - Ability to capture transient events and dynamic features that are cloud covered
  - Ability to collect in-situ surface data, ie. water content, types of organisms
  - Ability to collect sub-surface data
  - Ability to return home for recalibration of instruments
  - *Fluid features are mobile, and their shape and movement is not predictable*

- *What benefit does ASF provide?*
  - Observations through high-level goals
  - Supervisory fleet management of robotic platforms (coordination)
  - Analysis of environmental science data to use in decision making process (collaboration)
    - Optimal path planning and replanning
    - Identification of science phenomena
    - Adaptation to dynamic environments

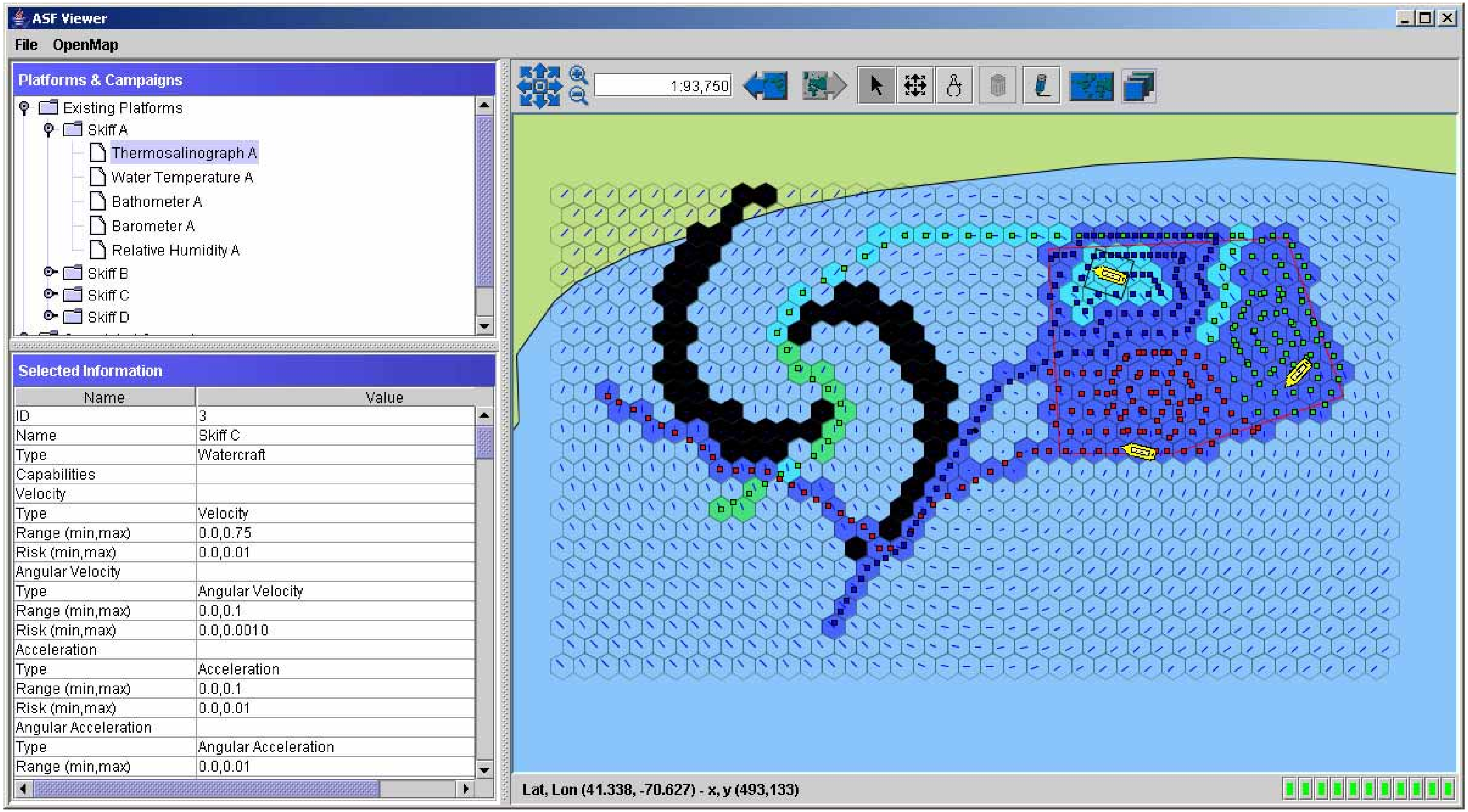
ASF Goal Definition

Goal definition:

- User specifies when the campaign will start and end
- User specifies the characteristics of the goal to be measured, along with the platforms to use for the observation
- User selects the region of interest to be modeled by specifying coordinates, or selecting a region on a world map.
- User submits the goal



ASF Operation



ASF Development Plan

- Phase A - FY04
  - Demonstrated basic coordinated multi-platform region mapping based upon high-level goal definition *in a simulated environment*
    - *3-4 Simulated OASIS Platforms*

- Phase B - FY05
  - Demonstrate collaborative multi-platform objective region mapping based upon high-level goal definition *in an ocean eddy using dye*
    - *6 OASIS Platforms*
  - Demonstrate coordinated geological survey based upon high-level goal definition *on MERS*
    - *3 Personal Exploration Rovers (PERs) Rovers*

- FY05 and Beyond - Infusion
  - FY05 NOAA OASIS infusion, proposed $4M to deploy OASIS fleet to monitor weather off the East Coast
  - Transfer to other applications and domains
    - Collaborative observations with the Personal Exploration Rovers (PERs) developed at Carnegie Mellon
    - Tetrahedral Walkers under development at GSFC Code 600

ASF Development Plan (cont.)

- FY05 and Beyond - Research
  - **SCALABILITY (>6 platforms):** We need to consider large numbers of platforms/sensors in order to explore the possibilities of true "Sensor Webs".
  - **APPLICATION:** We need to explore and apply ASF to other domains to demonstrate the robust capabilities of the system.
  - **MORE COMPLEX SCIENTIFIC GOALS:** The goals defined for the OASIS testbed are basic. We have to consider the possibility of dynamically changing the goals in real-time, and having much more complicated scenarios.
  - **ROBUST FLEET RECOMMENDATION:** We would like to explore the possibility of determining the optimal fleet to be used given a high-level goal definition. The fleet recommendation would be presented to the user in early iterations, but we should consider the possibility of dynamically changing the fleet make-up in real-time.
  - **ROBUST FLEET MANAGEMENT:** The ASF is designed to be a "supervisory" infrastructure, however, we have to examine the system from the perspective of being a "supervisor" over the collaborating team of robots, in addition to a "supervisor" over non-autonomous platforms.
  - **OPTIMAL PATH PLANNING:** "Optimal", from the ASF perspective, means that environmental knowledge is used when planning paths for the platforms. ASF has designed an optimal path planner for the OASIS testbed. However, we must consider this element from a much broader perspective and the application to other domains.
  - **ADVANCED AUTONOMY /COLLABORATION:** Implement a target classification system that prioritizes targets of interest relevant for extra terrestrial space exploration. This includes adaptive classification and decision-making framework for in-situ robots/sensors supporting autonomous control.
  - **PREDICTIVE MODELING:** Integrate predictive modeling into the goal processing subsystem of the ETASS using Grid Technology. The predictive models will be used to drive changes in the team behavior using near real-time in-situ measurements received from the team of robots.
  - **INTELLIGENCE GATHERING:** Implement a data fusion and mining system to be integrated into the ETASS, including the collection and mining of preexisting data relevant to the high-level goal(s) to be processed to optimize the fleet coordination prior to execution of the goal(s).
  - **HUMAN INTERACTION:** Implement innovative methods for fusing and presenting data received by the team of robots to the human explorer in near real-time.